

Response of Particulate Optical Properties to Coastal Mixing Processes

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LONG TERM GOALS

Our long-term goals are to develop a better understanding of the relationships between upper ocean optical properties and particulate and dissolved seawater constituents, and to determine how these relationships are influenced by physical processes. Specific long term objectives include both predicting and modeling optical variability relevant for biological processes, such as phytoplankton photosynthesis, and retrieval of information about the biomass and activity of plankton from optical measurements.

OBJECTIVES

Spatial and temporal variability in particulate and dissolved material is a major source of optical variability in the upper ocean. The primary objective of the present work is to examine the interaction between physical processes and the properties, abundance, and optical importance of different particle types in coastal ocean waters. Specific project objectives are to refine individual particle measurement methods and develop approaches to use individual particle results for interpretation of both inherent and apparent bulk optical properties (IOP/AOP). The project comprises a combination of instrument development and field studies in coastal waters of the eastern US continental shelf.

APPROACH

The approach we have taken employs techniques for characterizing and assessing the optical properties of particles, using both *in situ* and ship-board instrumentation and both bulk and single particle methods. Our primary tools are flow cytometry for assessing individual particle light scattering and fluorescence properties, spectrophotometry for measuring bulk dissolved and particulate absorption spectra (including separation of phytoplankton pigment absorption from the bulk absorption via methanol extraction), and spectral underwater radiometry. We conducted flow cytometric and spectrophotometric measurements both on discrete water samples and with *in situ* instruments. *In situ*

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measurement provides the opportunity for relatively unperturbed sampling, with generally greater spatial resolution, while analysis of discrete water samples allows more detailed characterization of optically-active seawater constituents. We used our sampling methods during the Coastal Mixing and Optics (CM&O) field study in continental shelf waters south of Cape Cod, MA (40° 30' N, 70° 30' W).

WORK COMPLETED

With the completion of the Coastal Mixing and Optics field experiment and preliminary data processing efforts, our work during the last year has focused on publication preparation and detailed interpretation of observations collected in summer 1996 (R/V Seward Johnson cruise 9610) and spring 1997 (R/V Knorr cruise 150). We have continued to emphasize characterization of optically active particles, assessment of absorption and scattering properties of particulate and dissolved material (including size dependence for particles), and examination of apparent optical properties. General findings on optical variability in relationship to hydrographic differences between the two seasons have been submitted for peer-reviewed publication (Sosik et al. 1999, Blakely et al. 1999).

Most results reported to date have been for two 3-week time series, one sampled in each season. In addition, we have now analyzed cross-shelf transects conducted during each season and investigated the significance of diel variations in particle optical properties based on daily sampling with coarse resolution (3 times per daylight period) and one intensive sampling (~every 2 h for 30 h) conducted in the spring. We have also continued work on the role of different types and sizes of particles in determining bulk optical properties.

RESULTS

We have made significant progress toward explaining bulk optical variability based on individual particle observations. One example applies to diel variations. Despite processes such as advection and internal wave passage, which can mask bulk diel changes, we observed variations in both bulk and individual particle optical properties over the daily cycle (Figure 1). While the observed diel variability is smaller than that observed over vertical gradients spanning the water column or across time periods spanning extreme events (such as the summer hurricane and the spring phytoplankton bloom), diel changes were significant, particularly in near-surface waters. Examination of observed patterns supports the interpretation that diel variations in optical properties of the water column are primarily due to changes in cell-specific optical properties of phytoplankton as they respond to environmental forcing (Figure 1).

We also made substantial progress in our efforts to explore the role of different types and sizes of particles in determining total absorption coefficients. Based on flow cytometric measurements of red fluorescence from phytoplankton cells, we have estimated individual particle absorption cross-sections. We have compared total absorption by phytoplankton cells determined from these individual particle measurements with independent measurements of bulk absorption by phytoplankton pigments and found an excellent relationship (Figure 2). These results suggest that approximately 80% of the total phytoplankton absorption is generally accounted for by particles smaller than ~10 μm diameter, a finding which is consistent with the size-fractionated filtration measurements of Roesler. We are currently examining the size-dependence of absorption in greater detail.

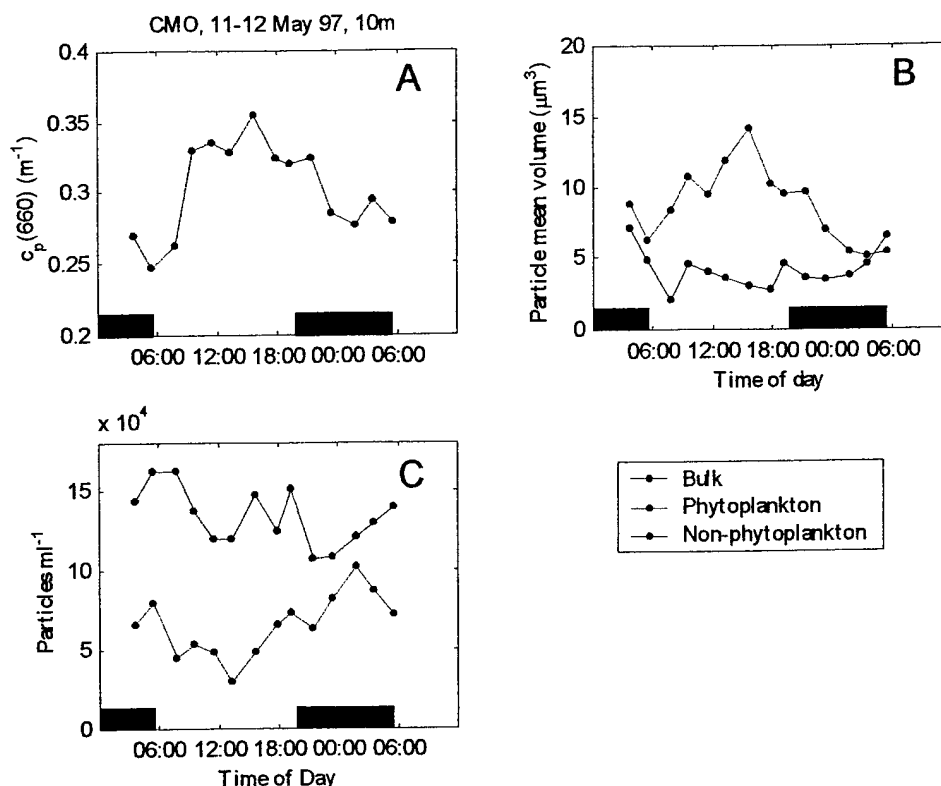


Figure 1. Diel patterns observed in optical and particle properties at 10 m depth during an intensive sampling period at the CMO central site in May 1997. These observations show the importance of changes in particle specific properties for bulk optical variability. Beam attenuation due to particles exhibited a marked change over the sample period, with minimum values observed during night and early morning hours (A). Examination of individual particle results from flow cytometry documents that the daytime increases in bulk attenuation coefficients are associated with increases in the size (and scattering cross-sections) of phytoplankton cells (B) and not with increases in the concentration of different types of particles (C). Phytoplankton exhibit cell growth during the daylight hours and division around dusk. The maximum concentrations of phytoplankton cells were actually found during the night when bulk attenuation was lowest.

IMPACT/APPLICATIONS

This project includes the development of improved techniques for analyzing marine particles and characterizing their optical properties. Our ability to independently quantify size distributions for phytoplankton and non-phytoplankton particles is a new contribution that will lead to better understanding of optical variability in the ocean.

TRANSITIONS

We have several on-going collaborations with other investigators participating in the CM&O program. Our results from sampling on mooring-turnaround cruises are being used by Dr. Tommy Dickey's group at UCSB for interpretation of observations from moored sensors. Radiometry results from the main

optics cruises have been provided to Dr. Ron Zaneveld at OSU for investigating relationships among diffuse attenuation for irradiance, remote sensing reflectance and absorption and scattering coefficients. Some results have been transferred to A. Robinson's group at Harvard for use in coupled physical – optical modeling and we have shared pigment, nutrient and size distribution results with Dr. Wilf Gardner's group at TAMU.

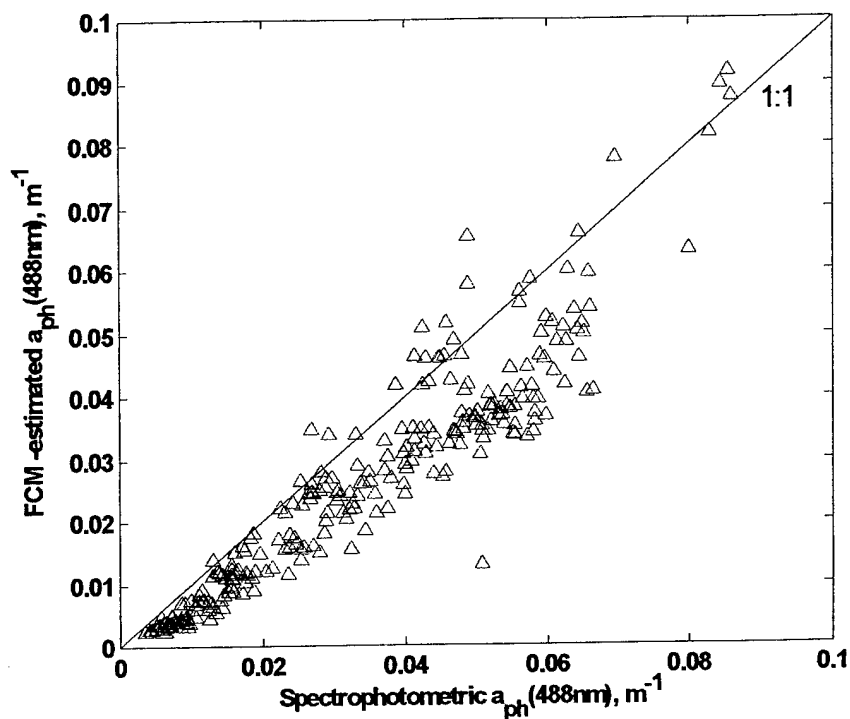


Figure 2. Scatterplot of phytoplankton absorption coefficients estimated flow cytometrically versus those measured using spectrophotometry on bulk samples from spring 1997. Flow cytometry estimates were derived by adding up individual cell absorption cross-sections determined from flow cytometric fluorescence measurements. High correlation provides support for the individual particle method, which we can use to examine details of the size dependence of absorption. Flow cytometrically derived estimates rarely exceed total absorption measured spectrophotometrically and usually represent a large proportion of the total, suggesting that we sampled most of the important cells. We have found similar results for late summer 1996.

RELATED PROJECTS

This project is closely tied with a NASA New Investigator Program award (Sosik) for investigating the regulation of local biological production of particles at the CM&O site and to explore the effects of changes in particle properties on ocean color. In addition, Olson is independently funded (NSF) to develop the in situ flow cytometer. Due to the interdisciplinary nature of the Coastal Mixing and Optics research initiative, this project is also closely tied to several others funded by ONR; specific collaborations and exchanges are underway with C. Roesler (pigment and particle absorption), S. Pegau and R. Zaneveld (IOP/AOP relationships), T. Dickey and G. Chang (particle absorption and modeling of primary production), and W. Gardner and J. Blakely (water properties and particle size distributions).

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Blakely, J. C., W. D. Gardner, I.D. Walsh, M. J. Richardson, S. Pegau, J. R. V. Zaneveld, C. Roesler, M. Gregg, J. MacKinnon, H. M. Sosik, and A. J. Williams, III. 1999. Stratification, storms, particles, and optics during the late summer and spring on the New England continental shelf. Submitted to J. Geophys. Res.

Sosik, H. M., R. E. Green, W. S. Pegau and C. S. Roesler. 1999. Temporal and vertical variability in optical properties of New England shelf waters during late summer and spring. Submitted to J. Geophys. Res.

PUBLICATIONS

Sosik, H. M., R. E. Green, W. S. Pegau and C. S. Roesler. Temporal and vertical variability in optical properties of New England shelf waters during late summer and spring. Submitted to J. Geophys. Res.

Blakely, J. C., W. D. Gardner, I.D. Walsh, M. J. Richardson, S. Pegau, J. R. V. Zaneveld, C. Roesler, M. Gregg, J. MacKinnon, H. M. Sosik, and A. J. Williams, III. Stratification, storms, particles, and optics during the late summer and spring on the New England continental shelf. Submitted to J. Geophys. Res.

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13. Abstract Spatial and temporal variability in particulate and dissolved material is a major source of optical variability in the upper ocean. This research program is aimed at developing a better understanding of the relationships between upper ocean optical properties and particulate and dissolved seawater constituents, and to determine how physical processes influence these relationships. We are refining individual particle measurement methods and developing approaches to use individual particle results for interpretation of both inherent and apparent bulk optical properties. The work comprises a combination of instrument development and field studies in coastal waters of the eastern US continental shelf. Results to date emphasize the importance of particles, especially phytoplankton, in determining vertical and temporal optical variability on the continental shelf. Physical processes have been found to contribute to optical variability most often indirectly through their effect on phytoplankton distributions, but major storms can have more direct and immediate effects due to advection and resuspension.			
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